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ON THE

OCCASION OF PRESENTING TO JOHN ERICSSON THE RUMFORD MEDAL OF THE AMERICAN ACADEMY.

BY

Eben Norton

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LATE RUMFORD PROFESSOR IN HARVARD UNIVERSITY.

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ADDRESS.

We have met to place in the hands of Captain Ericsson the Rumford Prize, awarded to him by the American Academy of Arts and Sciences, in 1862. It seems appropriate to the occasion, so long delayed by the events of the war, to call to mind the claims which the Academy has thus recognized. They rest upon the just appreciation of the purpose of Count Rumford in founding the Premium. What that was we gather from his letter of bequest, his letter of explanation to Sir Joseph Banks, and his pursuits. A great part of his life was passed in experimental researches in the application of the sciences to the useful arts. He studied to economize fuel, and to improve the arts of illumination, ventilation, and cooking. While in Bavaria he sought to lessen the discomforts of the poor, as well by improved mechanical contrivances for domestic uses, as by fully thought out and practically effective systems of relief. His more purely scientific labors were most of them in the same field. He preceded by half a century the German Mayer in the revival of the hypothesis of Bacon, that "heat is motion." This was the happy interpretation of the experiment conducted by Count Rumford of boring a cannon in a trunk filled up with water, in which the vibration imparted to the metal ultimately brought the water to the boiling-point. His scientific memoirs will be a lasting monument to his fame; but the Premium he established has provided, in an especial manner, for the perpetuation of his name, by forever associating with it a large class of the most useful inventions among men. In the

year 1796 he founded, in the American Academy of Arts and Sciences, and also in the Royal Society of England, a prize to be awarded for "improvements or discoveries in light or heat." The scope of the Premium was specially defined in a letter addressed the year following to Sir Joseph Banks, President of the Royal Society, in which he says: "The objects more particularly had in view to encourage, are such practical improvements in the generation and management of heat and light as tend directly and powerfully to increase the enjoyments and comforts of life, especially in the lower and more numerous classes of society."

The first Rumford Medal, in this country, was awarded to Robert Hare, for his invention of the Oxyhydrogen Blowpipe.

The second Medal was awarded to John Ericsson, "*for his improvements in the management of heat, particularly as shown in his caloric engine of* 1858."

CLAIMS OF ERICSSON.

To enable us to appreciate the full claim to this award, it would be necessary to review much of Captain Ericsson's career of invention for the last forty years and more, as it has been distinguished chiefly for the improvements it presents in the "generation and management of heat." Time will not permit this. I must pass, with a mere allusion, the *steam fire-engine* made in England, and used on the fires of the Argyle Rooms, the English Opera House, and Barclay's brewery, and that made for the King of Prussia, and put in operation in Berlin before the idea had been suggested in this country; and the *locomotive Novelty*, which attained a speed of fifty miles an hour in the great competition on the Liverpool and Manchester Railway, at the dawn of the new mode of travel in 1829. I must pass, too, the *improvements in distillation* and *the procuring of fresh from salt water at sea*, together with numerous inventions relating to *boilers* and *steam-engines*. It would be interesting to dwell on these in connection with the great issues to which they have con-

tributed, as it would on others not connected with heat, but still of great interest, such as the *water meter*, the *sounding apparatus*, the *balanced rudder*, and the device — recently revived — of conducting railway-trains up steep grades, by directing the power of the locomotive through lateral pressure applied on both sides of a central rail; but I must limit myself to the consideration of the principal inventions connected with improvements in the *naval* and *commercial marine* and the *caloric engine*.

That these belong to the class of "such as tend directly and powerfully to increase the enjoyments and comforts of life, especially in the lower and more numerous classes of society," will be obvious when we consider their connection with the development of industry and commerce and the preservation of States.

IMPROVEMENTS IN THE NAVAL AND COMMERCIAL MARINE.

The distinguishing characteristics of the vessels of war of the ancients were, their power to take position without regard to winds or currents; their ability to run down an antagonist, for which the bow was armed with a metallic beak; the invulnerability of the propelling power, — the banks of oars working through the sides of the hull; and the sheltered condition of the fighting men, who could, nevertheless, from towers, direct their missiles to any quarter from which the foe might be approaching.

With the Battle of Actium, nineteen centuries ago, culminated the naval architecture of the ancients. Thereafter, no marked advance was made in any quarter of the world for a thousand years. The first great improvement, like the most recent, was the offspring of Scandinavian genius. The *sharp keel*, enabling the vessel to encounter turbulent waters, was devised by the fishermen from the eastern shores of the North Sea. From the same waters issued the vessels in which the adventurous Northmen led the way of discovery to the western shores of the Atlantic. The ships of the period were small. The army of William the Norman crossed the British

Channel in transports, some of which were inferior in tonnage to many of our fishing-smacks, and others but little exceeded our whale-boats or the launches of a man-of-war in size, and did not equal them in safety.

With the practical use of gunpowder it had been made possible to hurl projectiles to greater distances, and cannon were placed on shipboard. The ship-yards of the Adriatic sent out a class of vessels capacious and safe, — the armed argosies, suited to the wants of commerce. Out of these argosies grew the man-of-war, with its tiers of guns, — a structure singularly suited to display the pluck of the sailor. Though shot might pierce the sides of the vessel and scatter splinters among the gunners and crew, the hull more frequently survived in a naval engagement to become a prize to the victors. At the Battle of Trafalgar, though hundreds of shot were driven through the wooden walls, not a vessel was sunk. The introduction of the horizontal firing of hollow shot, to burst on striking, lessened the safety and with it the steadfastness of the gunners. Such shot were contemplated by the first Napoleon in his armament of the Boulogne fleet in 1805. They were constructed at about this time by Robert L. Stephens, and specimens are still preserved in the navy-yard at Washington. But as an instrument of offence in war it was reserved for the French officer, General Paixhans, to introduce, in 1820, the use of large guns on shipboard for the express purpose of throwing hollow shot to be exploded by percussion. These shells, penetrating the sides of ships and bursting within them, greatly intensified the sanguinary character of naval battles, and increased the importance of being able to take choice of position. Considerable actions were of course impossible without wind. The fleets could not manœuvre. Steam had come, it is true, to make vessels independent of wind and current. But with it came the side-wheels, the smoke-stack, and the boilers on deck, which placed the vessel at the mercy of the enemy's shot. Steamers proved useful as transports and despatch-vessels, but were unable to cope with the old ships of the

line. If the latter could not take choice of position so as to bring the broadside guns into service, the pivot-gun at the bow or stern, with a single happy shot, might pierce a boiler, or destroy a wheel, or smoke-stack, or the rudder-chains, and at once put an end to the supremacy of the steamer.

This brief sketch was necessary to enable us fully to comprehend the magnitude of the first great revolution in naval architecture since the introduction of steam.

It proposed to place the boiler, the machinery, and the propelling power — all the vital parts of the ship — below the water-line, out of the reach of shot and shell. It proposed the telescopic chimney, that might be elevated or depressed at pleasure, in connection with a centrifugal blower, that made the draught of the fire independent of the height of the chimney.

Without these elements of the modern war-ship, all the others, it will be seen, are of comparatively little moment.

A vessel was constructed expressly to illustrate these great improvements. Though built in England, it was called the *Francis B. Ogden*, — a name familiar as that of our consul at Liverpool. This may be regarded as the *first successful propeller*. The screw, boiler, and machinery were below the water-line. It performed its duty in all respects well, on an excursion to which were invited His Majesty's Lords Commissioners of the Admiralty, and Sir William Symonds, the distinguished surveyor of the navy; and what was the result? Did they welcome such an accession to the naval power of England? Was a new vessel ordered of adequate dimensions to fully test the proposed improvements? Far from it. There was never a happier illustration of the habitual conservatism of the British Government in the treatment of new projects, than the course of the Lords of the Admiralty on this occasion. After considerable delay, it transpired, as the result of the deliberation of the Admiralty Board, that it would be *impossible to steer a vessel where the propelling power was so near the rudder!*

It is not to be wondered at that our guest should soon after have sought appreciation in another hemisphere. He came to America, bringing with him the machinery of a second propeller, the *Robert F. Stockton*, (still in active operation, in 1866,) and introducing screw navigation to the New World. At a later period he built for the government the screw war-steamer *Princeton*, embodying the improvements illustrated in a smaller way in the *Robert F. Stockton;* and when her plans and performance had elicited the admiration of some of the first naval constructors and naval officers of the world, then the Lords of the Admiralty commenced altering the old ships of the line, and building an indefinite number of the new vessels of various sizes, adopting not only the mode of propulsion demonstrated in the *Princeton*, and the plan of placing the vital parts of the steamer below the water-line, but even the artificial draught and the telescopic chimney.

Here were taken, at once, two great strides in marine architecture, *the invulnerable propelling power* and *the screw.* Steam was rendered available in naval warfare. These improvements restored to ships of war the ability lost sight of with the triremes, to take choice of position; and placed the power to go into or come out of an action almost beyond the contingencies of shot and shell.

The inventions of Captain Ericsson bear date of 1837. Various other persons had attempted to find a practical solution for propulsion by the screw, but it remained to achieve the victory over all difficulties and give what the world needed, — success. English authorities concede this, as do the French, for whose government he furnished the plans for the *Pomone*, the first screw man-of-war in the French navy. We do not lose sight, in this sketch, of the steam-screw propeller put in operation on Kollec Pond, in the city of New York, by John Fitch, in 1796. It was very small, it is true, and very little like the propeller of modern times. The screw was a shaft with a single, continuous, deep thread, and its other appliances were equally crude; but it was the *first steam-screw propeller.* Its veteran inventor — who, like

too many sons of genius, reaped but indifferent reward for his labors for the good of mankind — wrote: "This will be the mode of crossing the Atlantic in time, whether I shall bring it to perfection or not."

With this revolution in naval architecture, which speedily spread through the British and French fleets, the world seems to have been satisfied, and it slumbered on till the experience of the Crimean War suggested the protection of ships against bursting shells. The vessel was to be coated with plates of iron, thick enough to crush the shells thrown against them. Soon the idea arose of plating thick enough to resist the penetration of solid shot. The *Gloire*, on the part of the French, and the *Warrior*, on the part of the English Government, were the first vessels constructed on the new principle. The plate was strong enough to resist the penetrating power of the smooth-bore sixty-eight pounder, then the best gun in the British naval service.

The adoption of Professor Treadwell's system of coil-guns, as produced by Sir William Armstrong, soon proved to the English Government that the *Warrior* four-and-a-half-inch plates were no longer impenetrable. Thicker plates were made for the already burdened hull, until the ponderous armor weighed it down as the coats of mail weighed down the knights of the Middle Ages. The full broadsides, extending high out of water, were still presented as targets to the enemy. Their vulnerability with improved ordnance was relatively even greater than before. These defects were in some degree redeemed by the adoption of the ram for running down the enemy's ship, — a measure so eloquently urged upon the government by Colonel Ellet years before the war, and so signally illustrated by the *Merrimack* in Hampton Roads and the fleet under Admiral Davis before Memphis.

THE MONITOR SYSTEM.

This was the condition of the problem of *armor against ordnance* in 1861. At that time our navy, with the exception of a few effective ships of the line, frigates, and sloops of war, had to be created, — a condition of things scarcely conceivable now that our iron-clads may fairly challenge the assault of the world. The outbreak of the Rebellion presented an emergency which called into activity the resources of our people. The Navy Department gave an attentive ear to the projects devised by men of inventive talent, and in no case with more fortunate results than in the first turreted vessel submitted by Captain Ericsson. If it was to the honor of the commission who advised the construction of so novel a ship of war, and the department which acted with such promptitude upon their counsel, it was no less to the credit of the projector and constructor, that, within ninety days from the date of the contract, the *Monitor* was launched, and two months later had achieved — to the glory of Worden, his officers, and crew — its life-work in Hampton Roads. The plans of the vessel had been suited to the facilities of existing work shops, and to the exigency that made the saving of time a possible condition of national existence.

Before the astonishment with which we viewed the naval conflict with the *Merrimack* had subsided, public attention was called to the claim that one of the distinguishing features of the *Monitor*, the revolving turret, was an English invention. Appeal was made to the publications of Captain Coles, in "Blackwood" and in the "Mechanics' Magazine," bearing date of 1860, in which it was pointed out that the breech-loading guns of a ship of war might be served on turn-tables, moved by hand, and covered with dome-shaped shields. The conception of Captain Coles, as illustrated under his own signature, exhibited a double row of cupolas on the otherwise flush deck of an old-fashioned sloop of war.

The Lords of the Admiralty gave to the plans of Captain

Coles the same distinguished consideration that had been vouchsafed to the earlier proposition of Captain Ericsson in regard to screw war-steamers. It was only after the success of the *Monitor* that Captain Coles obtained the hearing to which his high order of ability entitled him.

Of the relative merits of the system, appropriately designated by John Scott Russell, in his great work on naval architecture just published in London, as the "American iron-clad navy," the projector and builder of the *Great Eastern* says: —

"It is a creation altogether original, peculiarly American, admirably adapted to the special purpose which gave it birth. Like most American inventions, use has been allowed to dictate terms of construction; and purpose, not prejudice, has been allowed to rule invention.

"The ruling conditions of construction for the inventors of the American fleet were these: the vessels must be perfectly shot-proof; they must fight in shallow water; they must be able to endure a heavy sea, and pass through it, if not fight in it.

"The American iron-clad navy is a child of these conditions. Minimum draught of water means minimum extent of surface protected by armor. Perfect protection means thickness to resist the heaviest shot, and protection for the length of the whole ship; it also means perfect protection to guns and gunners. Had they added what our legislators exact, that the ports shall lie in the ship's side, nine feet above the water, the problem might at once have become impossible and absurd; but they wanted the work done as it could be done, and allowed the conditions of success to rule the method of construction.

"The conditions of success in the given circumstances were these: that you should not require the sides of the ship to rise much above the water's edge; that you should be content with as many guns as the ship could carry and no more.

"To do the work, therefore, the full thickness of armor required to keep out the enemies' shot was taken, but the ship was made to rise a few inches above water and no more; and so a narrow strip of thick armor, all along the upper edge of the ship's side, gave her complete protection. Thus the least quantity of thickest armor did most work in protecting the ship, engines, boilers, and maga-

zines. Next, to protect the guns, a small circular fortress, shield, or tower, encircled a couple of guns; and if four guns were to be carried, two such turrets carried the armament and contained the gunners. Thus, again, weight of armor was spared to the utmost, and so both ship and armament were completely protected.

"But the consequences of these conditions are such as we, at least for sea-going ships, would reluctantly accept. The low ship's side will, in a sea-way, allow the sea to sweep over the ship; and the waves, not the sailors, will have possession of the deck. The American accepts the conditions, removes the sailors from the deck, allows the sea to have its way, and drives his vessel through — not over — the sea to her fighting destination by steam, abandoning sails. The American also cheerfully accepts the small round turrets as protection for guns and men, and pivots them on a central turn-table in the middle of his ship, raising his port high enough to be out of the water, and then fighting his gun through an aperture little larger than its muzzle.

"By thus frankly accepting the conditions he could not control, the American did his work and built his fleet. It is beyond doubt that the American *Monitor* class, with two turrets in each ship and two guns in each turret, is a kind of vessel that can be made fast, shot-proof, and sea-proof."

It is now admitted that no weather is too severe for a monitor that has a tight deck and tight deck-openings. The larger vessels, of the *Dictator* and *Monadnock* types, have been reported, by such experienced officers as Admiral Porter, Commodore Rogers, and Chief-Engineer Ziegler, to be capable of performing any sea-service. "The easy-rolling and good-steering qualities of the *Dictator* are not surpassed by any iron-clad afloat." Chief-Engineer Ziegler says of the *Monadnock*, after six thousand miles of sea-service, — "All agree that she is a perfect, successful, sea-going monitor."

Scott Russell says: —

"It will be noticed that the arrangements of the turret are very different from Captain Coles's arrangements. The whole turret is on the upper deck, exposed to shot; it is not carried on a revolving set of rollers, but is pivoted on the centre, which seems to carry most of its weight by means of an iron trussing, from which it is,

as it were, suspended; and it slides on a smooth metal plate lying on the deck. The turret is worked by a small pair of donkey engines working on tooth-gear, and the ports are covered by hanging blocks. When we consider the extreme rapidity which attended the execution of the project, we must say that the original *Monitor* was a remarkable success, and that she was a type of an entirely new class of war-ship.

"It is curious and instructive to observe how differently the system has been developed in America and in England; in the one case the sudden abandonment of all the conventionalities of a ship, and in the other the studious retention of old forms and ways, admitting the innovation with the greatest possible amount of reluctance and seeming aversion."

Any question of originality in point of time between Captain Ericsson and Captain Coles is effectually set at rest by a letter and illustrative diagram, bearing date 1854, addressed by Captain Ericsson to the Emperor Napoleon, of which I hold in my hand a printed copy. It will be seen that all that is characteristic in Captain Coles's invention, to wit: the revolving turn-table and its cupola shield, were anticipated by some six years.

It is not too much to say that with the *Monitor* a second revolution takes date in naval architecture within a period of twenty-five years. In this vessel, and more especially in those of the *Dictator* and *Monadnock* classes, besides a hull containing all the vital parts of the vessel below the water-line, alike invisible to an enemy and invulnerable, we have a revolving turret, capable — like the narrow edge of the low deck — of indefinite increase of armor, and of carrying and serving amidships the most powerful ordnance that can be devised; a wheel-house within the turret and sharing its protection; a ram of powerful construction, in which the deck acts as a wedge to penetrate and bear down an adversary; armor-plate as effectually protecting the stern as the bow and sides; an impregnable chimney and artificial draught; an even motion that permits the service

of the guns almost regardless of winds and waves; a system of ventilation which sweeps the atmosphere of the whole habitable vessel under the grate-bars; and a system of bunkers, which, when cleared of coal, may be filled with water to lower the deck and put the vessel in fighting trim, or emptied to make her light and high for speed.

The system, in a word, provides for the safe and successful working of guns however large, and presents a combination of advantages, both for defence and aggression, to be sought for in vain in any contrivance based on the form of the old line-of-battle ship.

THE CALORIC ENGINE.

Let us turn now to the *caloric engine.*

The idea of employing air in the propulsion of machinery is of early date. Papin, of Marburg, to whom we owe, among other inventions, the digester, the vacuum by steam, and the safety-valve, conceived the notion of compressing air by water power or other agency, and transmitting it through tubes to distant points, to be applied to operate machinery. This proposition was followed, after a long interval, by that of heating the compressed air on its transit, as proposed by Medhurst toward the close of the last century. Since then, the patents taken out for various forms of air-engines in the Old World and the New number several hundreds. They class themselves under three principal heads: —

1st. Such as use the same volume of air over and over again, alternately heating and cooling it, wholly or partially; of which there are various forms, including — beside some of Ericsson's — Stirling's, Hazeltine's, Parkinson & Crossley's, McDonough's, and others.

2d. Such as use the volatile products of combustion with the air, discharging at each stroke; like Ericsson's *flame-engine*, Bennett's, Baxter's, Sir George Cayley's, Gordon's, Drake's, Whipple's, Shaw's, and Roper's.

3d. Such as take in air at ordinary atmospheric pressure,

heat it by contact with heated metal, and discharge it at each stroke; like Ericsson's, Reach's, and Wilcox's.

It would be an endless, and for the purposes of this occasion a needless task to attempt to present, if justice could be done, the claims of all these exhibitions of thought, labor, and triumph over great mechanical difficulties. It is our duty only to point out the relative significance of the part in them performed by the recipient of the Rumford Premium.

Ericsson's first air-engine, called by the inventor the *flame-engine*, belonged to the second class; in which the products of combustion pass through the working parts of the engine. His second engine, in point of time, was of the third class.

In 1826, a Scotch clergyman, the Rev. Dr. Robert Stirling, and John Ericsson, applied to the British Government for patents for motive power actuated by heat and atmospheric air.

Stirling's engine was founded on the old idea of producing an alternating expansive force by moving a solid body back and forward within a closed vessel containing atmospheric air, heated at one end and cooled at the other. Ericsson's was founded on the idea of taking in a fresh supply of air at each stroke, heating and discharging it into the atmosphere. Robert Stirling, associating himself with his brother James, steadfastly pursued his chosen line of invention till about 1840, when the Dundee air-engine was produced. It is not known that this engine, which for several years gave very good satisfaction, has ever been repeated. The principal difficulties consisted in finding material which would sustain the intense heat of the fire, and in the necessity of supplying a large amount of water for cooling purposes.

Ericsson brought into practical operation, in 1827, the first double-cylinder engine actuated by heated air discharged at each stroke into the atmosphere. One cylinder and its piston served to supply the air. With the descent of the piston, air was taken in through valves above, while that below was driven over the heater into the working cylinder. With the rise of the piston in the supply cylinder, the air

from above was transferred through a lateral passage to the bottom of the cylinder, filling the space as the piston rose. The air driven into the working cylinder, acquiring expansive force by the heat received in its transfer, operated the piston in the open working cylinder, communicating motion to the machinery.

THE REGENERATOR.

By using a common passage, containing a number of straight pieces of metal, alternately for the heated air escaping from the working cylinder, and for the transfer of the cold air from above to below the piston, in the supply cylinder, in which case the piston moves *in equilibrio*, Captain Ericsson, in 1837, introduced the *regenerator*, already applied by him to the engine of the first class in 1833, and in regard to which there has been so much and such ill-informed discussion. Could the parties to the opposing views have come to a common stand-point, they would have discovered themselves reënacting the combat of the gold and silver shield. The use of the heat of the heated air after the air has performed its work in the working cylinder, by warming closely arranged sheets of metal or coarse wire netting and then absorbing this heat from the metal by the air in its passage, in constant volume, from one side to the other of the piston in the supply cylinder, is no more mysterious than the economy of the use of water condensed from waste steam and returned at a temperature below 212° to the boiler. There is this difference, however, that it is possible to heat the air passing through a regenerator to a temperature much above 212°. What the inventor claims to be a regenerator, and Franchot called a calefactor, the disputant would perhaps call an economizer.

DIFFICULTIES AND REWARDS OF INVENTORS.

The progress of discovery and invention in the case of the caloric engine, with its attendant constant collision with difficulties, anticipated and unforeseen, with its unflinching

struggle continued through evil and through good report for thirty-five years, and the calm conviction of ultimate success which animated it, can never be fully known or appreciated. It required, moreover, the perennial inspiration of capital, proverbially wanting in faith, and yet never appealed to in vain by Captain Ericsson in this city of merchants, "some among whom, like those of ancient Tyre, are princes."

While the history of the caloric engine illustrates the grandeur of the coöperation which its inventor has enjoyed, it illustrates also the conditions of success in invention which even genius must recognize. The development of a conception requiring mechanical devices, serial processes, trials, modifications, and a period of probation, involves capital. The duty of capital is self-increase. It demands, as a prerequisite to investment, satisfaction in regard to prospective profit, or, if there be chances of loss, that they be balanced by chances of corresponding or greater gain. How are these chances of gain to be secured to capital? By precluding competition for a limited time, that the losses incidental to development may be reimbursed. And this is done through the protection afforded by the patent laws. Without this protection few of the great achievements of the age would have made their mark. The steam-engine, the locomotive, the photograph, the telegraph, the wood-screw, the threshing-machine, the reaping-machine, the sewing-machine, the Hoe printing-press, the improvements in arms, and in domestic economy, warming, and illumination, the analine colors, vulcanized rubber, the propeller, the caloric engine, and the monitor, have become what they are, and rendered their services to civilization chiefly through the method of coöperation between the inventor and the capitalist which the patent laws have provided.

It has sometimes occurred that men of science — unlike Liebig, Gay-Lussac, and Hoffman, Brewster and Wheatstone, Watt, Fairburn, and Ericsson — have declined to avail themselves of this provision for rendering their discoveries or inventions useful to their fellow-men. Where, in such

cases, there has been genuine invention, promising increased comfort and culture to man, it has usually happened that the labor and thought were bestowed in vain; and for the obvious reason, that, as all may engage in the supply of the new product, the capital required for unavoidable expenditures at the outset cannot have its needed protection. The author and publisher are aware of this natural law. The copyright is the recognition of their necessities. Where, on the other hand, the invention, as may be assumed in the great majority of cases, has advanced only to the stage of difficulty, where the steadfastness of the experimenter and the resources of varied creative power are called into action, as the essentials to success, the giving over of what has been done to the public is not to be wondered at; nor should it be a matter of surprise, that, to the authors of the latter class of inventions, especially, the patent laws seem to have been devised for another class of minds than their own.

INVENTION AND SCIENTIFIC DISCOVERY.

It sometimes happens, after the crown of success has been attained by the faithful experimentalist, that the germ of the hypothesis upon which he bestowed his thought and labor is claimed to have been entertained, at an earlier period, by some one else.

The claim alleged is for the specific scientific discovery which is said to underlie the invention. Now, scientific discoveries are of various classes and degrees of merit. There are simple facts, which, like material gems, reward an explorer in a fruitful field, and demand little effort beyond the exercise of attention and a capacity to collect and record. There are others in which the laws of physical force and chemical composition are determined by systematic experiment. There are still others in which abstract relations are brought to light, as in mathematics; and others in which the properties conferred upon matter by organic life are the subjects of research, as in physiology. Achievements in these several fields have a certain value as an evidence of culture and a

title to social consideration. There is another class in which success is sometimes rewarded by pecuniary as well as social distinction. It is the class in which the object of discovery is a device by which the forces of nature or the qualities of matter may be made to render new service to civilization.

In this class, discovery has usually, for its first step, the perception or appreciation of a want. Its next step is speculation as to the devices by which the want may be met. Then there is the production of a crude contrivance, by which to test the soundness of the speculation. Then come modifications and new trials, and ultimately what seems success. Then comes expansion of the process, approaching a working scale. Trial on the larger plan reveals fresh imperfections; new relations appear, and new expedients have to be resorted to. The devices which, at the commencement, were distinguished on account of their complexity, are replaced by others of marked simplicity. Again success seems to be attained. Now comes the grand economy and organization of the enterprise for rendering the discovery available and useful.

The rank of the scientific discovery, or series of discoveries, which make up such an invention, is high in proportion as the intrinsic difficulties to be overcome have been great, and as the investigation and solution of the problem presented have been exhaustive, and low in proportion as the difficulties were inconsiderable, and as the investigation has been superficial and the solution defective.

It rarely happens that all the stages of an important and useful discovery of this class are presided over by one mind. More frequently the earlier and later stages fall into different hands. In this event the rewards are divided. The nearer one is to the conclusion of the series, the larger uniformly is his measure of material return. Where all have been the offspring of one mind, the honors and pecuniary emoluments enter alike into the reward. Where the naked speculation or suggestion only can be claimed, or where a crude device merely had been proposed and success predicted, the author

will be assigned a place in the world's esteem, distinguished in some degree in proportion to the clearness and detail of his plans and predictions. If it be not as high as the man of suggestion sometimes deems his due, it is because the applause of mankind seems to be reserved for its heroes, — the men who have not only encountered difficulty, but made its conquest, — rather than for its men of speculation, whose influence on the well-being of the race is more transient, or, if lasting, less direct.

The common sense of the world has made a uniform, and, we must believe, a just discrimination, in its award of merit to him who, patiently following the lead of a conception, has brought to successful issue and recognition new agencies for advancing civilization, rather than to him who, equally with the former, had the same happy conception, and had it even at an earlier date, but neglected the duties nature prescribes as the condition of fruition.

"The step from the first more or less vague conception of a new truth to its conclusive demonstration is a matter of far more importance and difficulty than the happy and sometimes, to all appearances, intuitive guesses which have invariably preceded every great discovery. Newton formed a right estimate of his own claims, when he ascribed his success to the patient and laborious pertinacity with which he kept fast hold of an idea, until, by long thinking and varied experiment, he has proved either its truth or its falsehood." — *Quarterly Review: Newton as a Scientific Discoverer.*

HISTORY OF THE CALORIC ENGINE OF 1858.

Let us trace the steps by which the caloric engine of 1858 was evolved.

First, in 1827, we had the two-cylinder engine, with a piston in each cylinder.

In 1837 the fly-wheel above and regenerator were added to the two-cylinder engine. With some modification of details, this engine was reproduced by Wilcox in 1859–60.

In 1839, in connection with the regenerator, came two pistons operating in one cylinder, one supply and the other

working, and with them a device for compressing the air at the instant of its passage from the supply cylinder to be heated. The feature of two pistons in one cylinder reappeared, with the regenerator in the head of the working piston, in Reach's engine, the plan of which was published in 1854, though it is not known to have been carried out to a working model.

Then came a series of experimental engines, resulting, in 1851, in the differential engine for the *caloric ship*, — a vessel which, at the outset, yielded a speed of seven knots, but was ultimately abandoned, not from any inherent defect of principle, but because the wants of commerce required faster ships.

In 1855 we had the supply and working piston in one cylinder, with the regenerator and the compression of air, in which the supply piston worked *in equilibrio* at the time when the working piston was nearly stationary.

In 1856 was added the quickened motion at the conclusion of the inward stroke of the supply piston.

In 1858 came the device of the alternating blast of cold air over the lubricated surface of the cylinder, by which the temperature was kept below that at which oil suffers injury. The difficulty of preventing the oil from burning had been pronounced by eminent authority in England to be insurmountable, because of the high temperature indispensable to the air-engine, — debarring, therefore, forever, success to the caloric engine. To this device were united, within one cylinder, the supply and working pistons, the telescopic tube, the fire-pot, and the regenerator. To render these effective were devised the combination of the fly-wheel, rock-shaft, crank, and lever movements, and the system of connecting rods, by which the air of the supply cylinder is compressed at the instant when the working cylinder is nearly at rest, by which the working piston is held *in equilibrio* during the transfer of the air to the heater through the regenerator, and by which the necessary direct, reversed, uniform, accelerated, and retarded motions required for operating the pistons and valves

are produced and connected with each other. It is difficult to conceive of a higher theoretical and mechanical triumph.

I do not dwell on the series of air-engines constructed by Captain Ericsson to operate by alternately heating and cooling a confined body of compressed air, of which the first was built in 1833, and one of the most recent was nearly completed for the *Primero* at the outbreak of the Rebellion. It is enough to say, that, in comparing the earlier with the later engines, there is a marked development of the capabilities of the principle, and corresponding progress in invention.

It has been impossible to go into detail with each of Captain Ericsson's air-engines, of which there have been produced above thirty, distributed through more than this number of years, differing in essential particulars of invention, or designed to test some question to be answered only by experiment, — as it would be to review the discussions of the caloric engine, in which Ericsson, Rankine, Joule, Napier, Regnault, Barnard, Norton, and a crowd of other writers, French, German, English, and American, have taken part. No one who comprehends the action of Stirling's earlier engine, or of Ericsson's of 1833 or 1837, — which, with the regenerator attached, would do an amount of duty to which it was utterly inadequate with the regenerator detached, — or of the action of the caloric engine of 1858, or of Wilcox's, — which with the escape and supply ports closed, and the air of the working cylinder returned alternately to and received from the supply cylinder, will run for a long time after the fire has been withdrawn, — can now doubt, that, upon the main point, the function of the regenerator, the claims of Ericsson have been sustained.

I cannot omit to allude to the experimental researches of Captain Ericsson to determine the relations of elasticity to temperature in suddenly compressed air, as compared with air so slowly compressed as to have the heat removed as rapidly as produced. They are important as having been

conducted on a scale so large as to escape the errors of previous experimenters, and being therefore more trustworthy as a guide to engineers. It is to be hoped that the details of these researches, together with all the others Captain Ericsson has made, connected with heated air, steam, and naval architecture and armament, will at no distant day see the light, that their legitimate influence may be felt upon the spirit of invention and the progress of the mechanic arts.

Captain Ericsson: At the time the vote of the American Academy of Arts and Sciences conferring upon you the Rumford Premium was passed, I had the honor to be Chairman of the Rumford Committee, and, you will remember, signified my wish to relieve myself of the trust imposed upon me; but as this formal act and the simple ceremony appropriate to it have been postponed in consequence of the pressure of the war, in which you, sir, have borne so conspicuous a part, the custody of the vote and medal has been continued with me to the present time.

I have the honor now to place in your hands a certified copy of the vote passed by the Academy at its annual meeting, June 10, 1862. It is as follows: —

> "*Voted*, That the Rumford Premium be awarded to John Ericsson, for his improvements in the management of heat, particularly as shown in his caloric engine of 1858."

In now handing to you the gold and silver medals which have been prepared in accordance with the statutes of the Academy, I beg to congratulate you upon the honors you have won through a life of research and experiment, devoted to the promotion of the prosperity and well-being of mankind, in the field contemplated by the illustrious founder of the Rumford Premium.